Engineering at the National Science Foundation

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Program Director
CMMI ENG

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www.nsf.gov

Current Programs / Future Directions

ENG Overview

- Mission and Vision
- Current Organization

ENG Divisions

- Organization
- Priorities
- Nuggets

ENG Priorities

- National Priorities
- Frontier Areas
- Unique Programs

ENG Overview

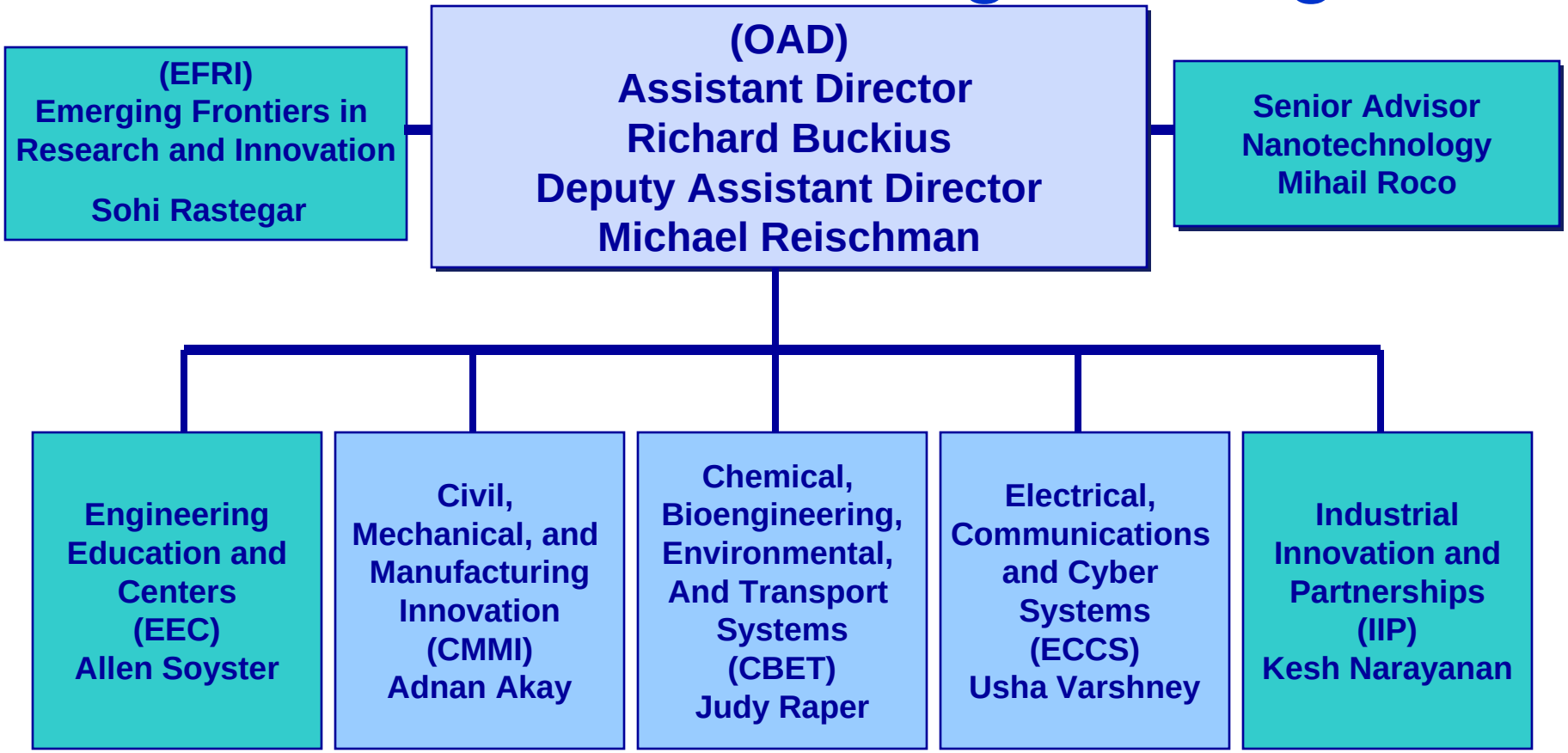
NSF Directorate for Engineering Mission/Vision

- **Mission:** To enable the engineering and scientific communities to advance the frontiers of engineering research, innovation and education, in service to society and the nation.

- **Vision:** ENG will be the global leader in advancing the frontiers of fundamental engineering research, stimulating innovation, and substantially strengthening engineering education.

ENG Divisions

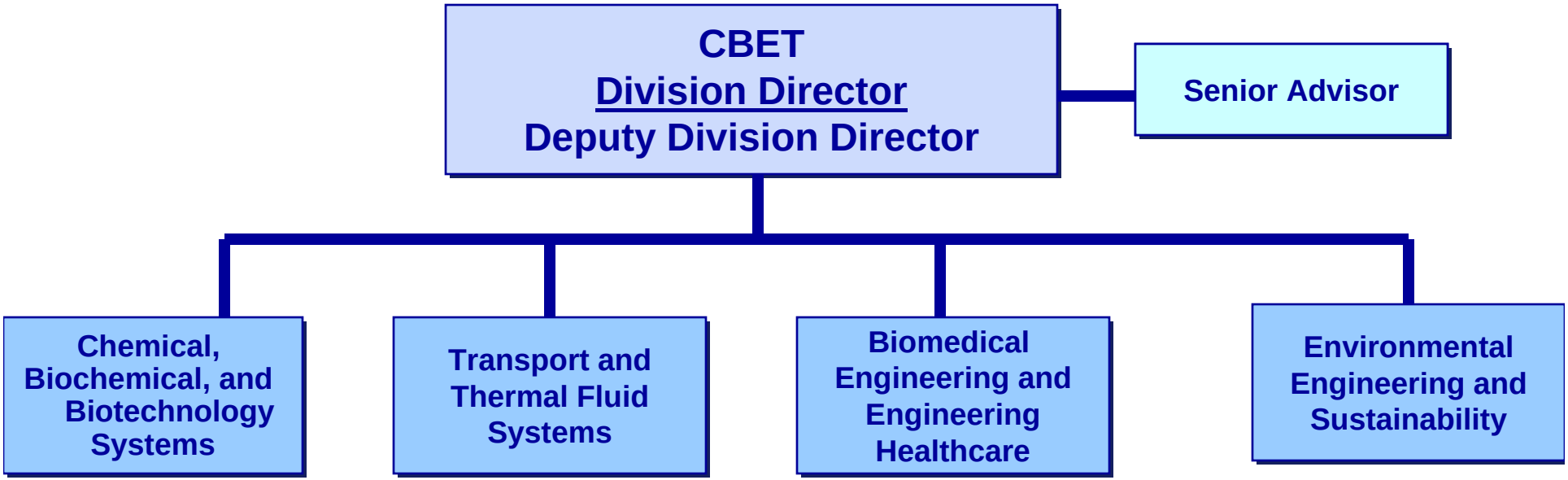
Directorate for Engineering



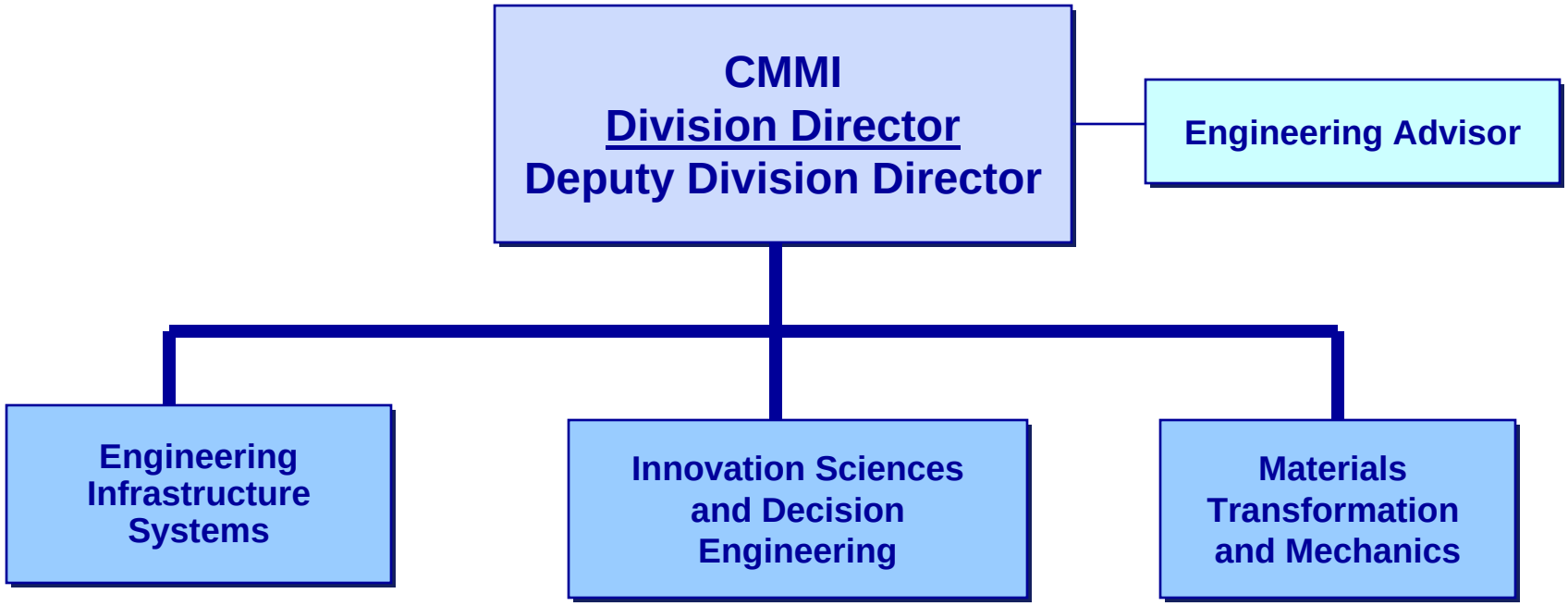
EFRI Office

- **Support higher risk, higher payoff opportunities leading to:**
  - **new research areas for NSF, ENG, and other agencies**
  - **new industries or capabilities that result in a leadership position**
  - **significant progress on advancing the "cutting edge" or a grand challenge**
- **Successful topics would likely require:**
  - **small- to medium-sized interdisciplinary teams with significant funding**
  - **the necessary time to demonstrate substantial progress and evidence for follow-on funding through other established mechanisms**
- **The recommended investment range from $3 million, with a time frame of 3 years, but can be up to 5 years**

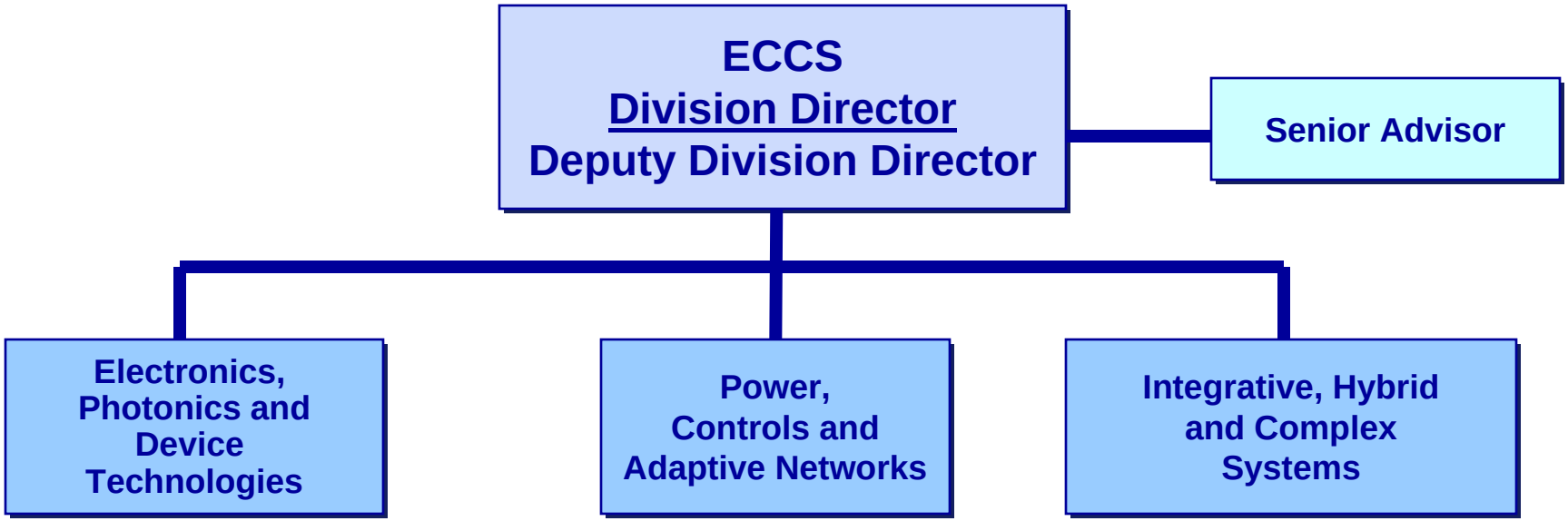
Chemical, Bioengineering, Environmental, and Transport Systems



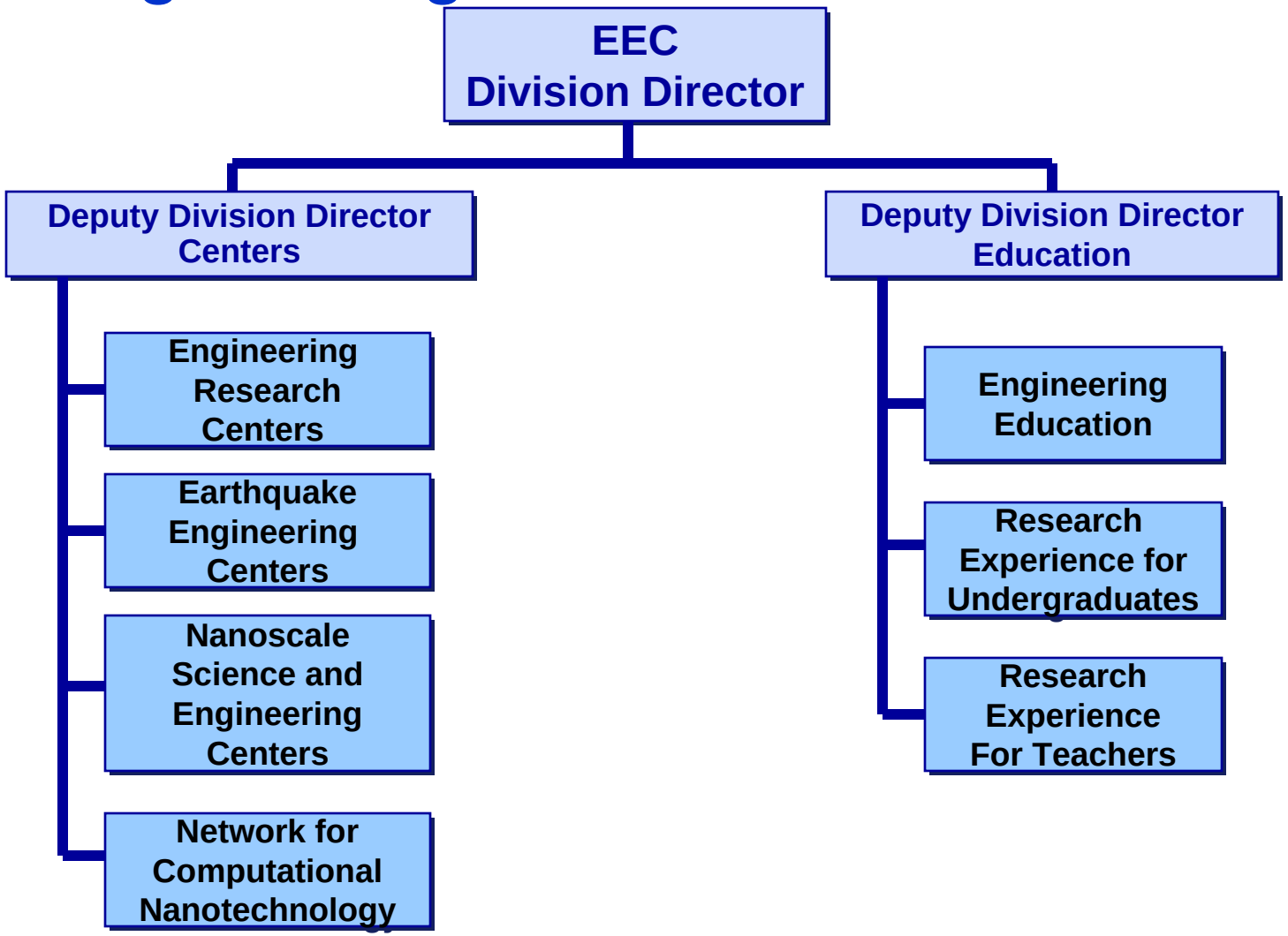
Civil, Mechanical, and Manufacturing Innovation



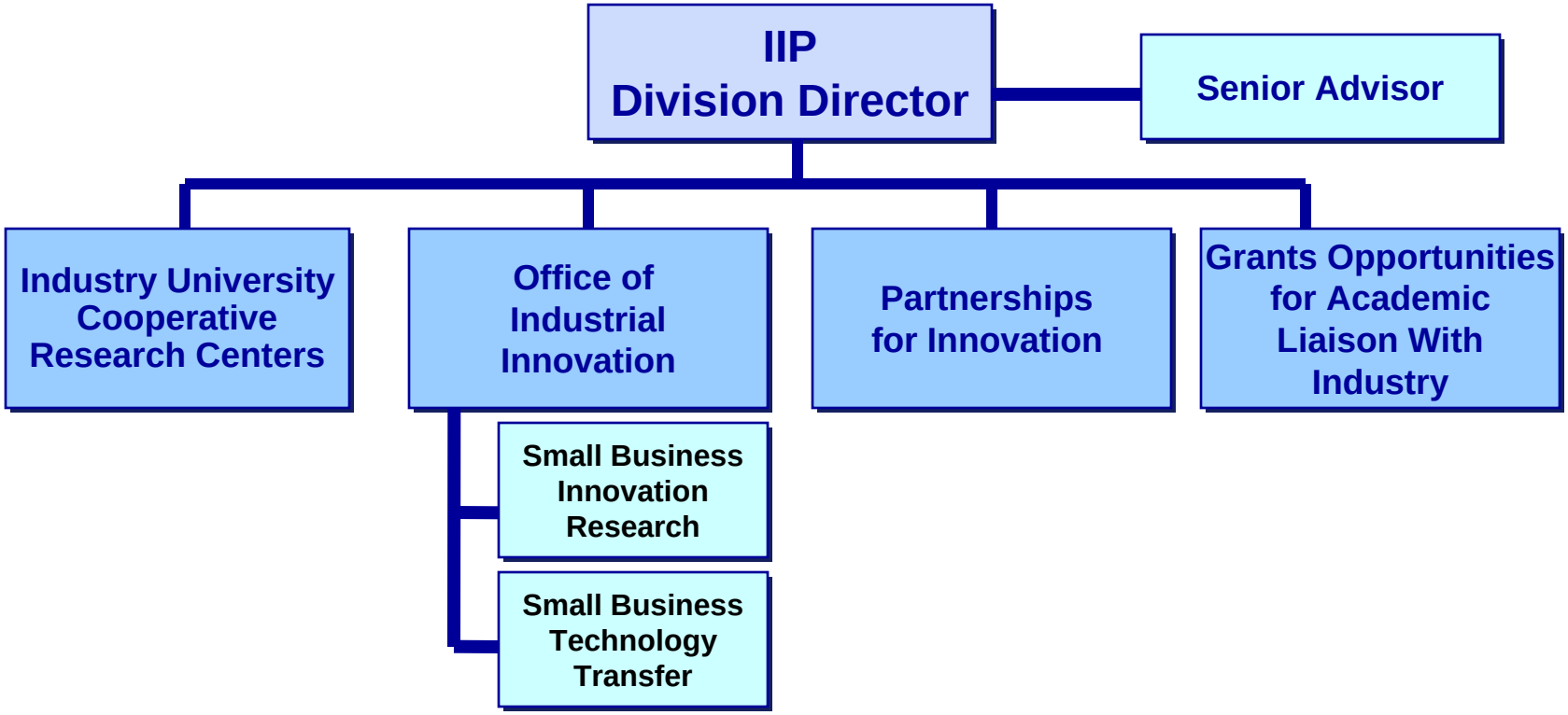
Electrical, Communications and Cyber Systems



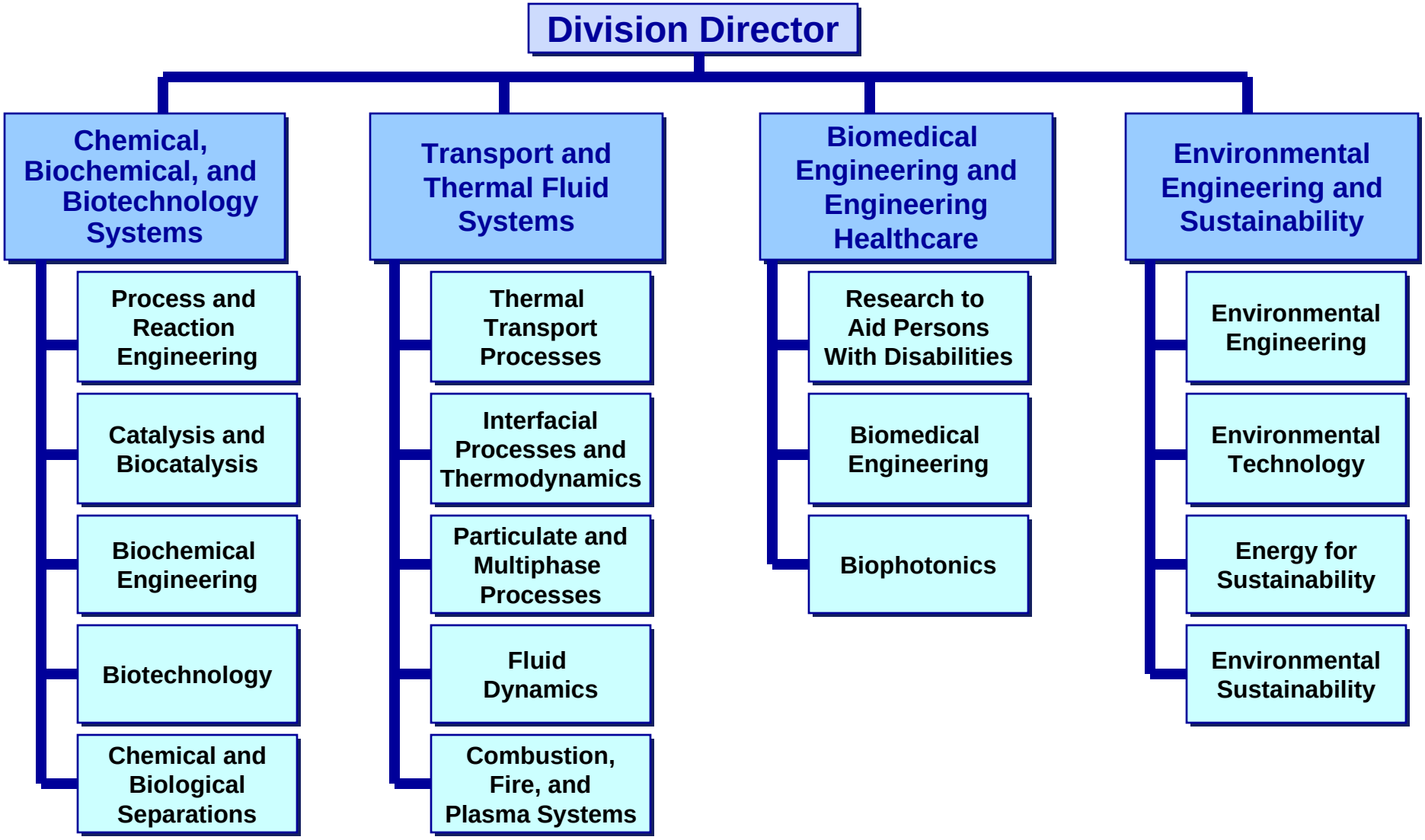
Engineering Education and Centers



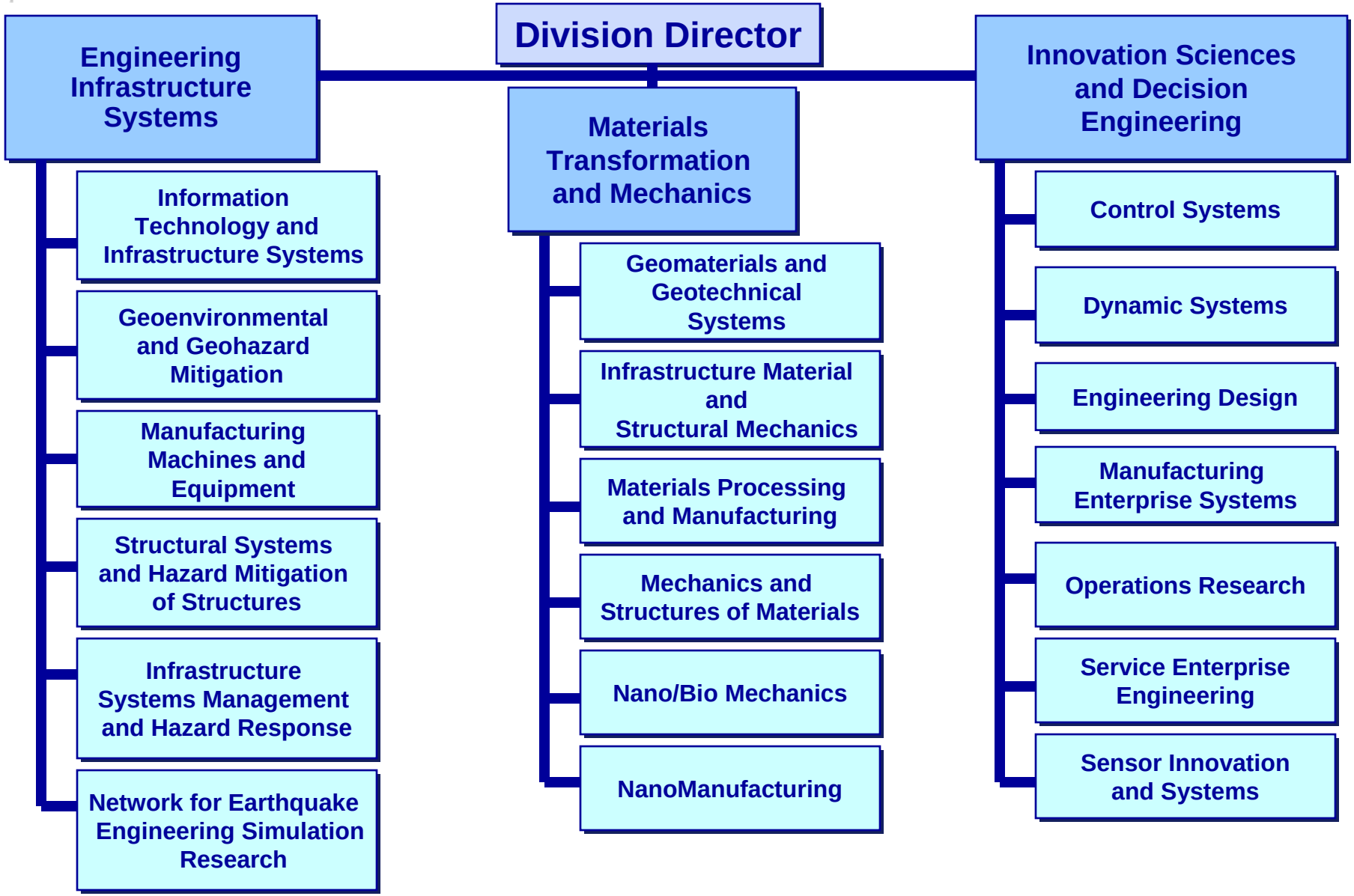
Industrial Innovation and Partnerships



Chemical, Bioengineering, Environmental, and Transport Systems



Civil, Mechanical, and Manufacturing Innovation



Electrical, Communications and Cyber Systems

Division Director

Electronics, Photonics and Device Technologies

Topics

- Micro / Nanoelectronics
- Molecular Electronics
- Flexible Electronics
- Spin Electronics
- Bioelectronics
- Micromagnetics
- Optoelectronics
- Sensors and Actuators
- MEMS/NEMS
- Power Electronics
- Microwave Photonics

Integrative, Hybrid and Complex Systems

Topics

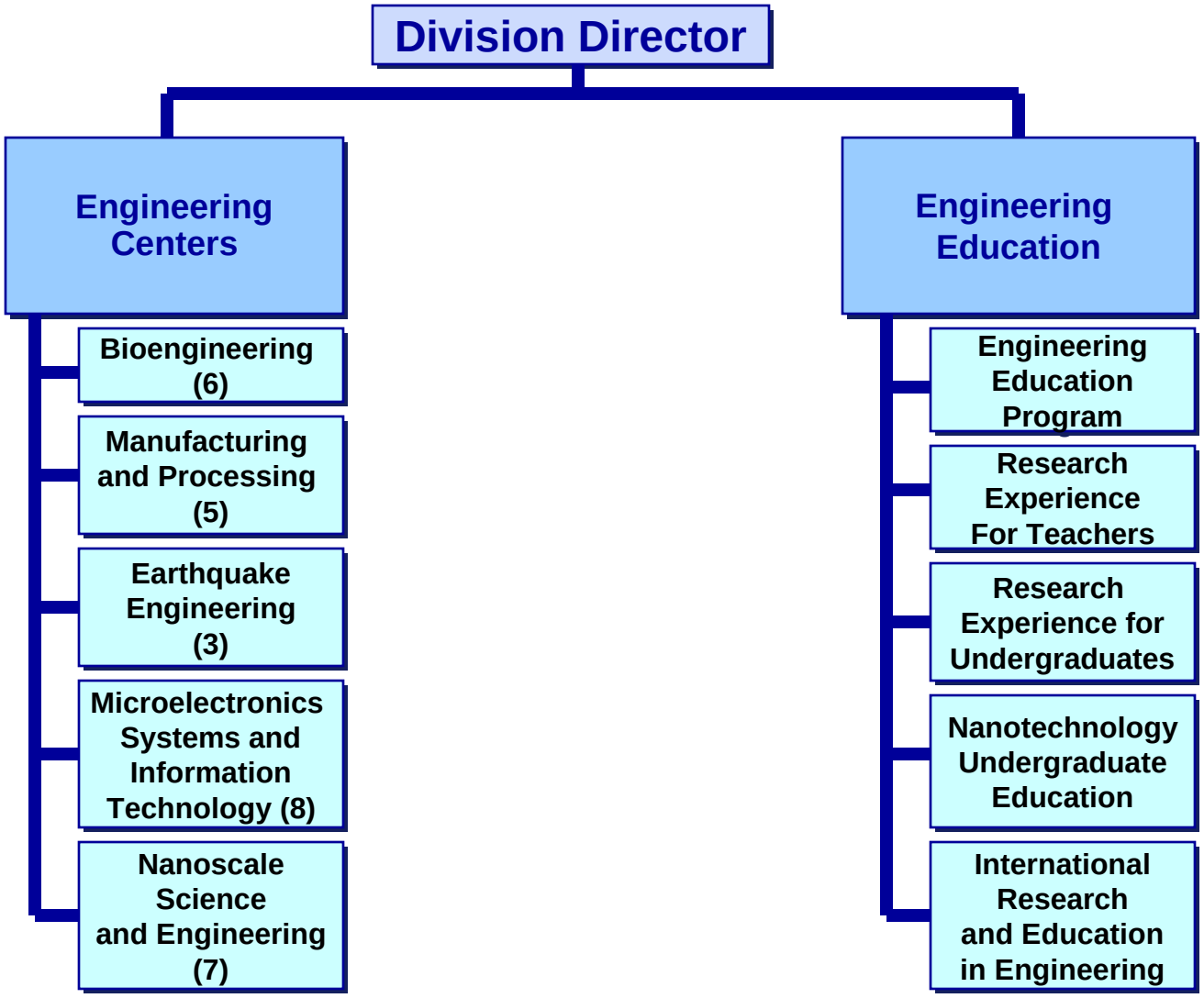
- System-on-a-chip
- System-in-a-package
- Diagnostic and Implantable Systems
- Organic and Silicon-based Hybrid Systems
- Optical, Wireless and Hybrid Communications Systems
- Cyberengineering Systems

Power, Controls and Adaptive Networks

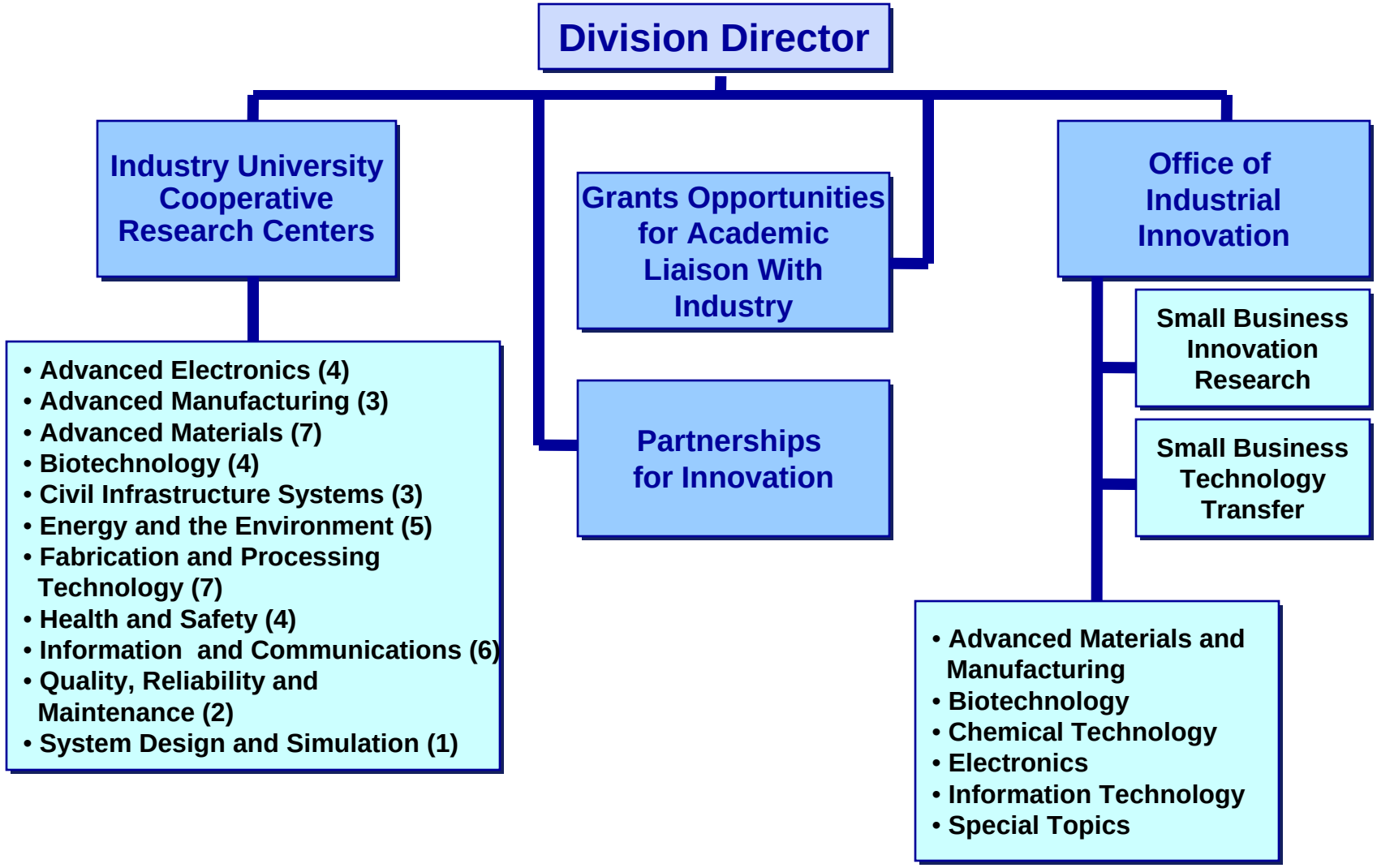
Topics

- Embedded, Distributed and Adaptive Control
- Telerobotics
- Power and Energy Networks
- Sensing and Imaging Networks
- Quantum Modeling and Simulation of Devices and Systems
- Adaptive Dynamic Programming

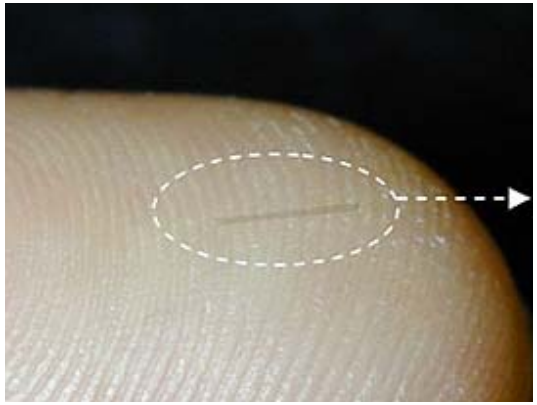
Engineering Education and Centers



Industrial Innovation and Partnerships

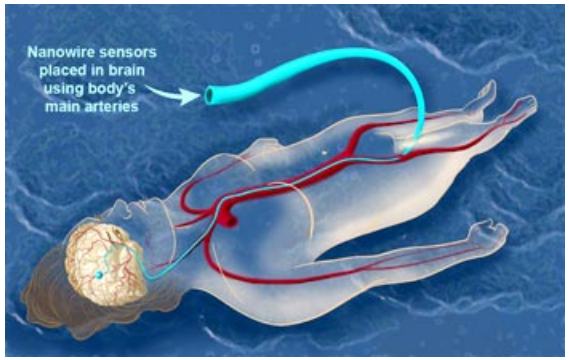


CBET: Nuggets and Discoveries



Credit: *Michael S. Strano, a professor of chemical and biomolecular engineering, University of Illinois, Urbana-Champaign*

Carbon nanotubes are yielding a new class of biological sensors. This glass capillary tube, shown here on a fingertip, has been loaded with glucose-sensitive nanotubes. The capillary tube keeps the nanotubes confined, but has porous walls so that glucose molecules can get to them.



Credit: Zina Deretsky, National Science Foundation, Rodolfo R. Llinás, New York University School of Medicine

Engineers envision an entire array of nanowires connected to a catheter, which could be guided through the circulatory system to the brain. Once there, the nanowires would branch out into tinier and tinier blood vessels until they reached specific locations. Each nanowire would then be used to record the electrical activity of a single nerve cells, or small groups of nerve cells.

CBET: Nuggets and Discoveries

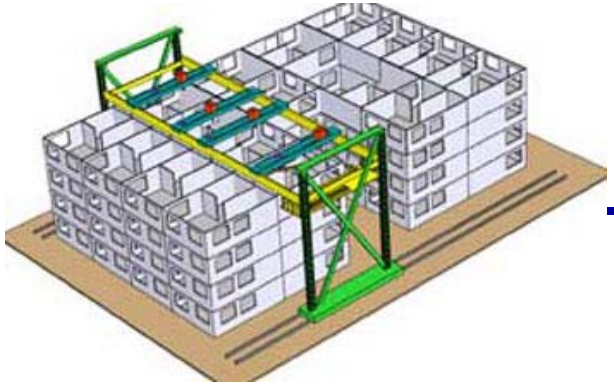
Hong Liu and Bruce Logan of Penn State University and Stephen Grot of Ion Power, Inc.

By harnessing the activity of billions of bacteria, researchers have engineered a bio-filtration system that produces hydrogen gas while cleaning wastewater.

Credit: NSF. Andy Ruina, Mechanical and Aerospace Engineering, Cornell

Researchers at Cornell, MIT and the Delft University of Technology in the Netherlands have developed a new breed of powered, energy efficient, two-legged robots with a human gait. The engineers have crafted robots that can walk on level ground, in some cases using as little as one-half the wattage of a standard compact fluorescent light bulb.

CMMI: Nuggets and Discoveries



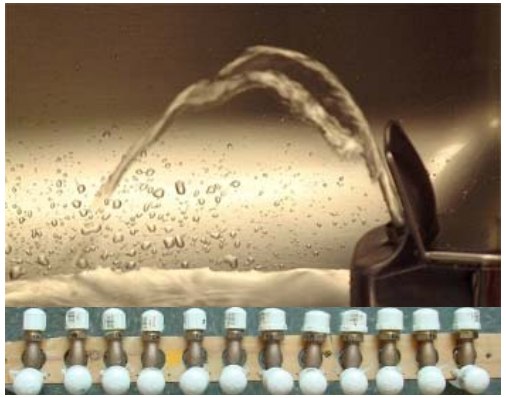
Credit: Dr. Behrokh Khoshnevis of the University of Southern California

Engineers have developed an automated home building technique that will make it possible to build a house from foundation to roof in less than 24 hours. "Automated Construction by Contour Crafting" consists of robots that deliver concrete through a jet.

One of the search and rescue robots.
Credit: *Robin Murphy, associate professor of computer science, University of South Florida*

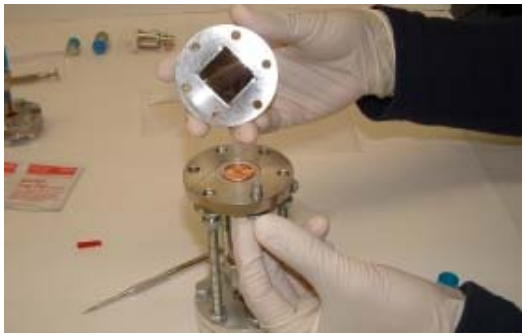
Shoebox-sized robots were deployed in rescue effort at “Ground Zero.” Graduate students and the experimental robots they helped to develop were among the early responders who joined the search and rescue efforts shortly after the Sept. 11 collapse of the World Trade Center towers.

CMMI: Nuggets and Discoveries



Credit: *Marc Edwards, Civil & Environmental Engineering, Virginia Tech*

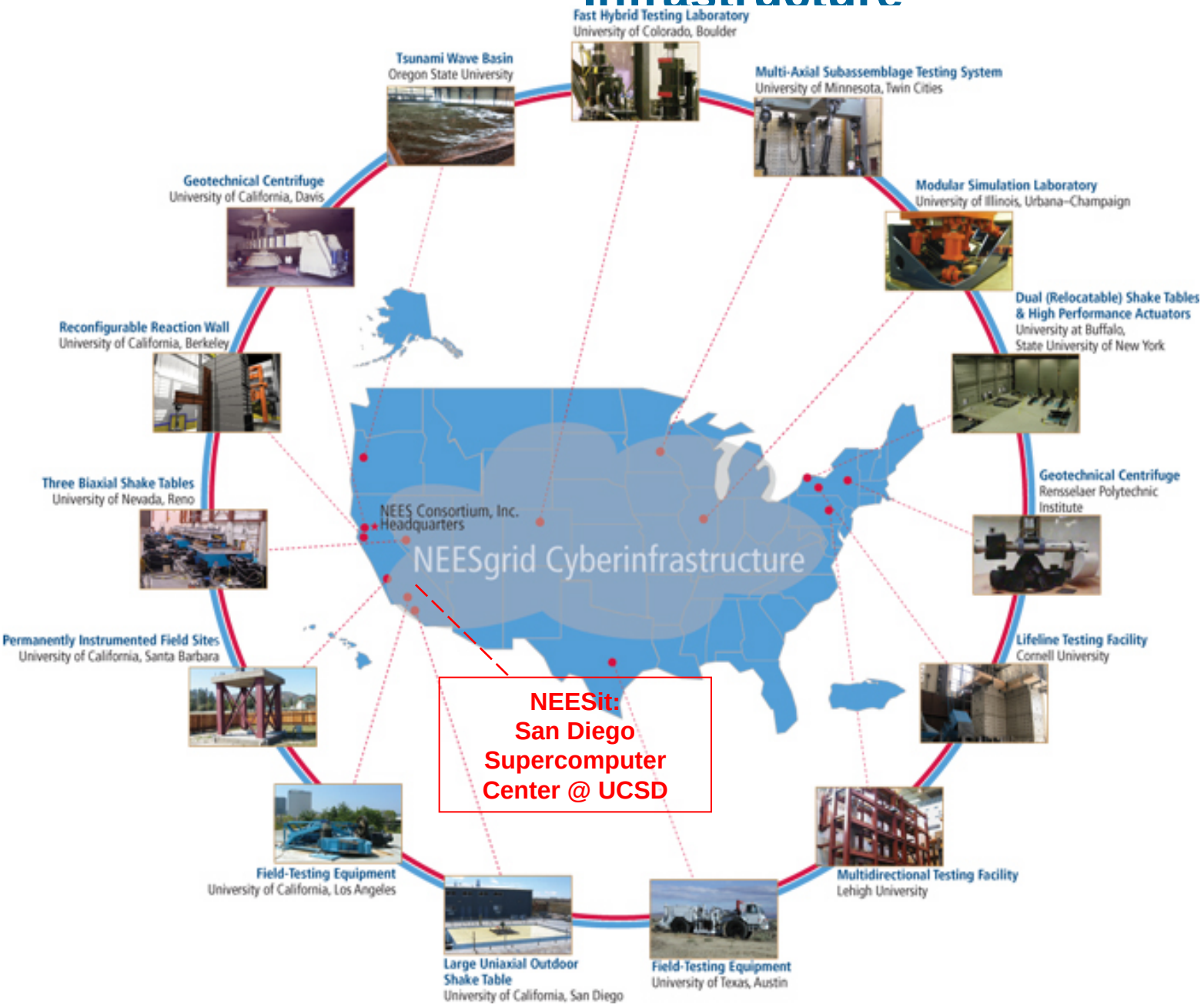
A new study of American National Standards suggests some of the lead creeping into tap water in metropolitan areas may be trace to valves and other components--not just pipes further from the home.



Credit: Wei Sun, University of Rochester; BetaBatt, Inc.

Using some of the same manufacturing techniques that produce microchips, researchers have created a porous-silicon diode that may lead to improved betavoltaics. Such devices convert low levels of radiation into electricity and can have useful lives spanning several decades.

NEES Shared Use Infrastructure

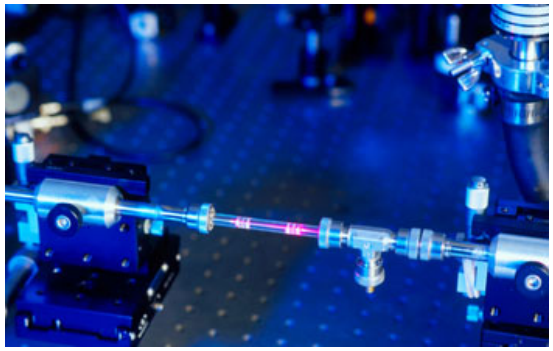


Outdoor Shake Table 7-Story Test Structure

Platen 12.20 m x 7.6 m
Max stroke 1.5 m
Max velocity 1.8 m/sec
Laminar soil box
Two adjacent refillable soil pits

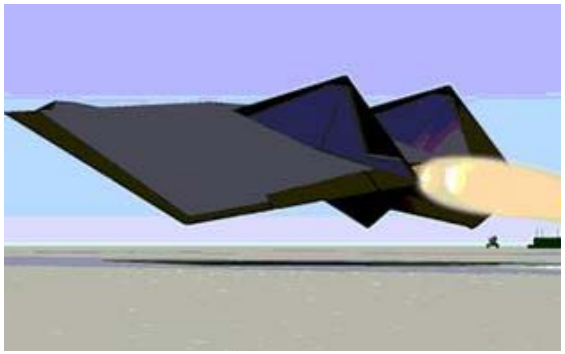
7-story reinforced concrete building test at UCSD NEES outdoor shake table showed that a structural wall with half the amount of reinforcing steel required by most building codes, but with more optimal layout, can better resist seismic loads. (Test funded by industry consortium)

ECCS: Nuggets and Discoveries



Credit: Henry Kapteyn and Margaret Murnane, *University of Colorado and the National Science Foundation*

Breakthrough brings laser light to new regions of the electromagnetic spectrum. A "waveguide" coaxes extreme-ultraviolet light waves into forming a tightly focused laser-like beam that will allow researchers to "see" tiny features and carve miniature patterns.



A side view of the new design
Credit: Ramon Chase, ANSER

Plasma engineering and brain-like control could increase aircraft speed, perhaps so much that we could reach earth orbit at the cost of an airplane ticket.

EEC: Nuggets and Discoveries

University of Wisconsin physicist
Cary Forest

A Madison Dynamo Experiment points the way to understanding Earth's core. In the full experiment, the one-meter wide, stainless steel shell is filled with molten sodium metal. (The prototype used water.) The metal is stirred so that its motions simulate the Earth's magnetic field-generating dynamos.

Credit: Duke University photo by Jim Wallace

Experiment uses biomolecules to write on a gold substrate. Duke University's Ashutosh Chilkoti explains how a nanoscale "pen" laid down thin trails of enzyme "ink," which then carved out the 400-nanometer-wide channels shown in the background.

ENG Priorities

ENG Aligns With National R&D Priorities

1. **Homeland Security R&D**: Research on sensors could raise the alarm at the first sign of chemical and biological attacks. Also, clusters of "smart" sensors could be scattered across a stretch of hostile territory to monitor traffic and troop movements.

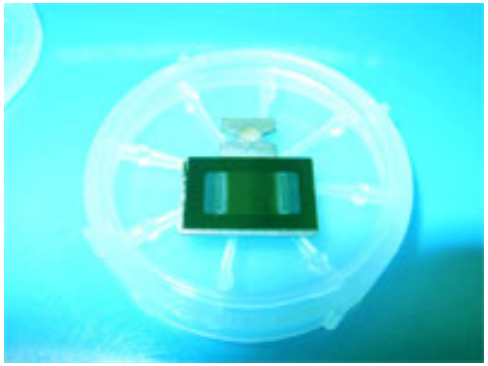
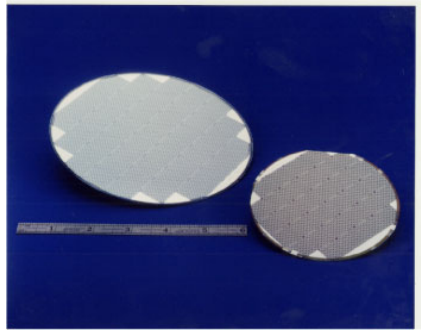


Image of the Schottky diode sensor. Courtesy of the University of California, Santa Barbara, Department of Chemical Engineering.

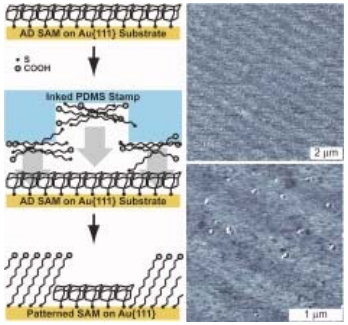
2. **High-end Computing**: ENG supports the development of high-end computers, including efforts in the Control, Networks and Computational Intelligence program, which centers on the analysis and design of intelligent engineering networks for control, communications, computation and energy.



Neural Network Learning on a chip. Chris Diorio, University of Washington and Impinj Inc.

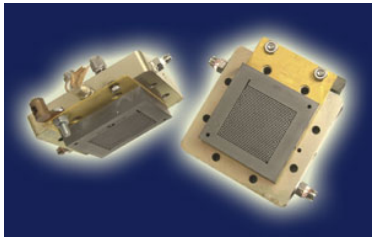
ENG Aligns With National R&D Priorities

3. **National Nanotechnology Initiative**: NSF leads the U.S. nanotechnology research effort, and the NSF Engineering Directorate is the focal point within NSF for this critical national research endeavor.



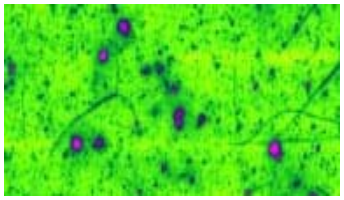
Penn State microdisplacement print process for nanofabrication

4. **Energy and the Environment**:ENG funds research in Environmental Engineering and Technology, including a focus on hydrogen fuel cell research.



Univ. South Carolina Proton Exchange Membrane Fuel Cell

5. **Understanding Complex Biological Systems**: ENG supports a wide range of programs that shed new light on complex biological systems, including interagency metabolic engineering research.



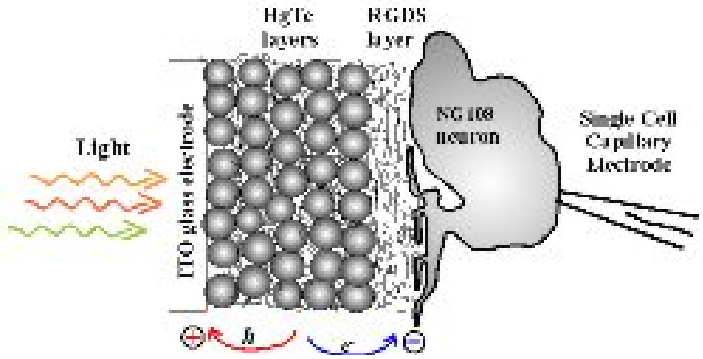
Nanomix carbon nanotubes for respiration monitoring.

ENG Frontier Research Areas

1. Biology in Engineering: Gene therapy, neural implant acceptance, nanobioelectronics, energy and the environment, etc.

Photoactivated Coupling of Nanoparticle Multilayers and Nerve Cells

Nanoscale composites are a tremendously abundant resource for new functionalities in biomaterials. A team of material chemists and physicists at Oklahoma State University and neurophysiologists and bioengineers at the University of Texas Medical Branch successfully interfaced neurons and nanoparticle film and observed ion/electron communication between them. This research will play a key role in the successful application of neuro-prosthetic devices.



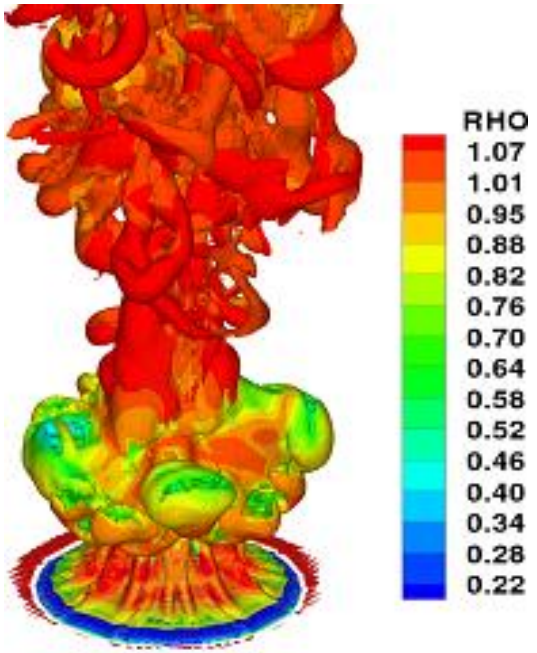
Credit Bruce Logan, Pennsylvania State University

ENG Frontier Research Areas

2. Complexity in Engineered and Natural Systems: neurons in the human brain, economic markets, power grid, etc.

Fire Phenomena

An advanced simulation is now better able to predict the complex interactions of how water mists and sprays suppress large-scale fires. This work will point the way to better fire suppression techniques to protect both our natural resources and infrastructure.



Credit: Paul DesJardin
SUNY at Buffalo

ENG Frontier Research Areas

3. Critical Infrastructure Systems: Agriculture and food, water, public health, emergency services, etc.

NEES: George E. Brown, Jr. Network for Earthquake Engineering Simulation

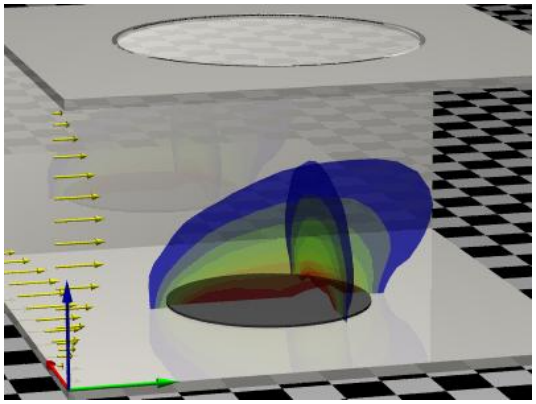
The NEES infrastructure (experimental facilities and cyberinfrastructure) facilitates a variety of innovative experimental approaches that will lead to a better understanding of how the built environment. NEES can also enrich lessons for K-12 students and teachers by making them "virtual partners" in the process of experimental discovery and analysis.

ENG Frontier Research Areas

4. Manufacturing Frontiers: New materials and zero waste use, nano and nano-bio manufacturing, convergence of bio-engineered discoveries and manufacturing innovations, etc.

Rapid Prototyping for Semiconductor Manufacturing Process Simulation

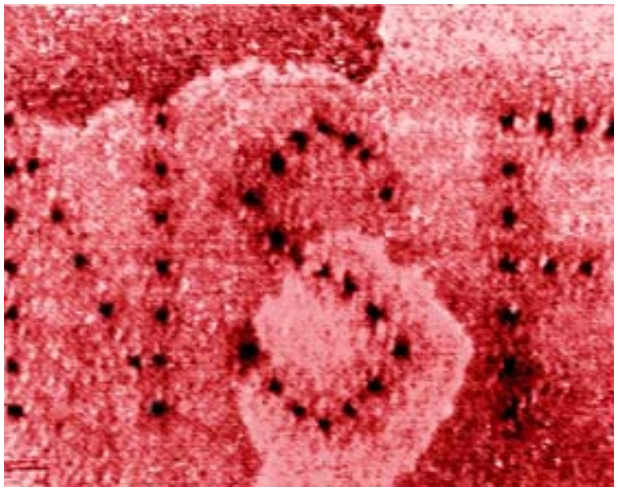
A new process developed at the University of Maryland uses complicated nonlinear models to predict poorly understood reactions. New methods predict the process parameters in Semiconductor Manufacturing, which will yield an order-of-magnitude improvement in computational efficiency in process manufacturing.



Credit: Raymond Adomaitis
Univ. of Maryland

ENG Frontier Research Areas

5. New Frontiers in Nanotechnology: Nano and Nano-bio manufacturing, nanoelectronics, etc.



Ajay Malshe (Principal Investigator)
University of Arkansas

Researchers Carve with Electricity at the Nanometer Scale

Researchers from the University of Arkansas, by applying electric current through a thin film of oil molecules, have developed a new method to precisely carve arrays of tiny holes only 10 nanometers wide into sheets of gold. The new system, called Electric Pen Lithography (EPL), uses a scanning-tunneling microscope, fitted with a tip sharpened to the size of a single atom, to deliver the charge through the dielectric oil to the target surface.

ENG Unique Programs

- Engineering Research Centers
- Nanoscale Science and Engineering
- Industrial Innovation and partnerships: Small Business Innovation Research & Small Business Technology Transfer
- Network for Earthquake Engineering Simulation

EEC Centers

- EEC's centers promote partnerships among researchers in different disciplines and between industry and universities.
- They focus on integrated engineered systems and produce technological innovations that strengthen the competitive position of industry.
- Engineering Research Centers (NSF 04-570)
- Industry/University Cooperative Research Centers (NSF 01-116)

Nanoscale Science and Engineering

- Support fundamental research and catalyze research and education in emerging areas of nanoscale science and technology.
- Includes biosystems at the nanoscale; nanoscale structures, novel phenomena, and quantum control; nanoscale devices and system architecture; nanoscale processes in the environment; multi-scale, multi-phenomena theory, and studies on the societal and educational implications of scientific and technological advances on the nanoscale.
- Supports Nanoscale Interdisciplinary Research Teams (NIRT), Nanoscale Exploratory Research (NER), and Nanoscale Science and Engineering Centers (NSEC)

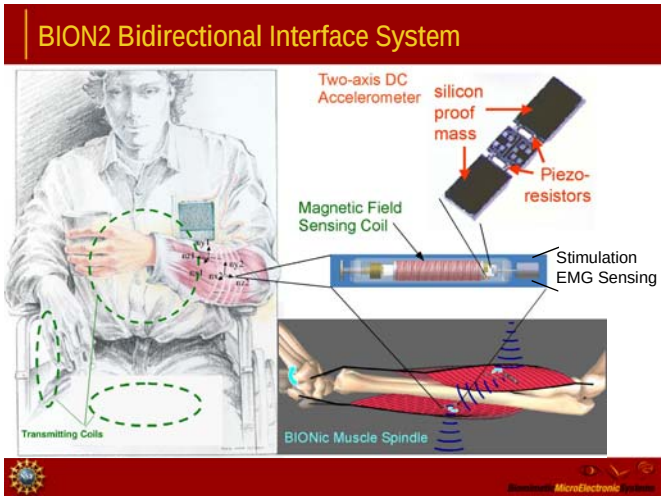
Industrial Innovation and Partnerships

- Through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, NSF supports important scientific, engineering, or science/engineering education problems and opportunities that could lead to significant commercial and public benefit.
- STTR requires researchers at universities and other research institutions to play a significant intellectual role in the conduct of each STTR project. These university-based researchers, by joining forces with a small company, can spin-off their commercially promising ideas while they remain primarily employed at the research institution.

ENG Themes

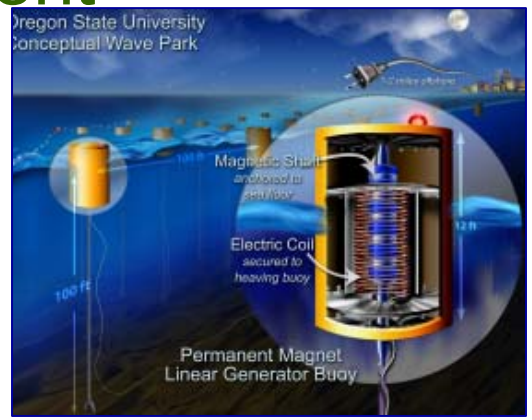
Complex Engineered and Natural Systems

- **Addresses unifying principles that enable modeling, prediction, and control of emergent behavior in complex systems ranging from critical infrastructure to the intersection of the life sciences and bioengineering.**
- **Includes critical infrastructure systems, such as the power grid, communications infrastructure, and health care; and bioengineering systems, such as molecular biomachines and biomimetic devices, the brain-computer interface, and new biophotonics imaging methods.**



ENG Themes

Energy and the Environment



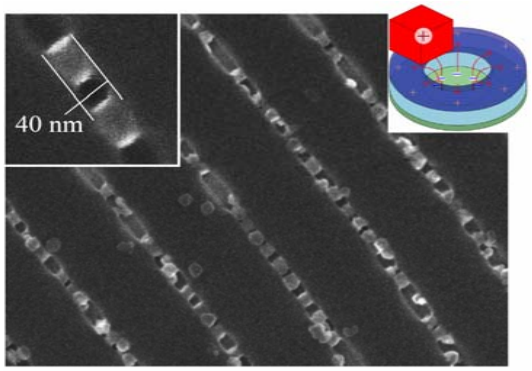
- **Environmentally and economically sustainable energy is among the most pressing concerns for this nation and the world.**
- **A new ENG program on *Energy for Sustainability* will be initiated in FY 2007.**
- **ENG's investments will directly impact national research goals:**
  - **Use of hydrogen, nuclear, and solar energy through basic research in materials; and**
  - **Research critical to nanotechnology, biotechnology, alternative energy, and the hydrogen economy through essential infrastructure.**

ENG Themes Innovation

- **What are the basic theories of innovation? Can innovation be taught? What are the elements that need to be integrated into engineering education to drive the nation's innovation engine?**

- **Innovation is a principal objective of engineering research and pervasive in ENG investments. ENG is uniquely able to integrate research, education, and innovation through existing programs:**
  - **SBIR/STTR**
  - **GOALI**
  - **I/UCRC, and**
  - **PFI.**

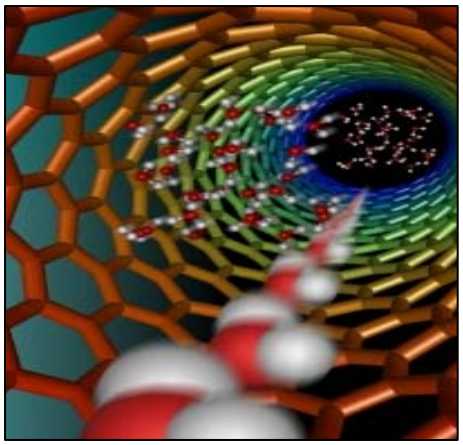
ENG Themes
Manufacturing Frontiers



- **Multiscale manufacturing – from fundamental metrology through atomic-scale control of raw materials – is needed.**
- **Innovation through manufacturing – especially nanomanufacturing – will ensure U.S. competitiveness.**
- **ENG's investments in manufacturing frontiers will directly impact the following national research goals:**
  - **World-class capability in nanofabrication and nanomanufacturing; and**
  - **Improved sensor and detection capabilities resulting in world-leading automation and control technologies.**

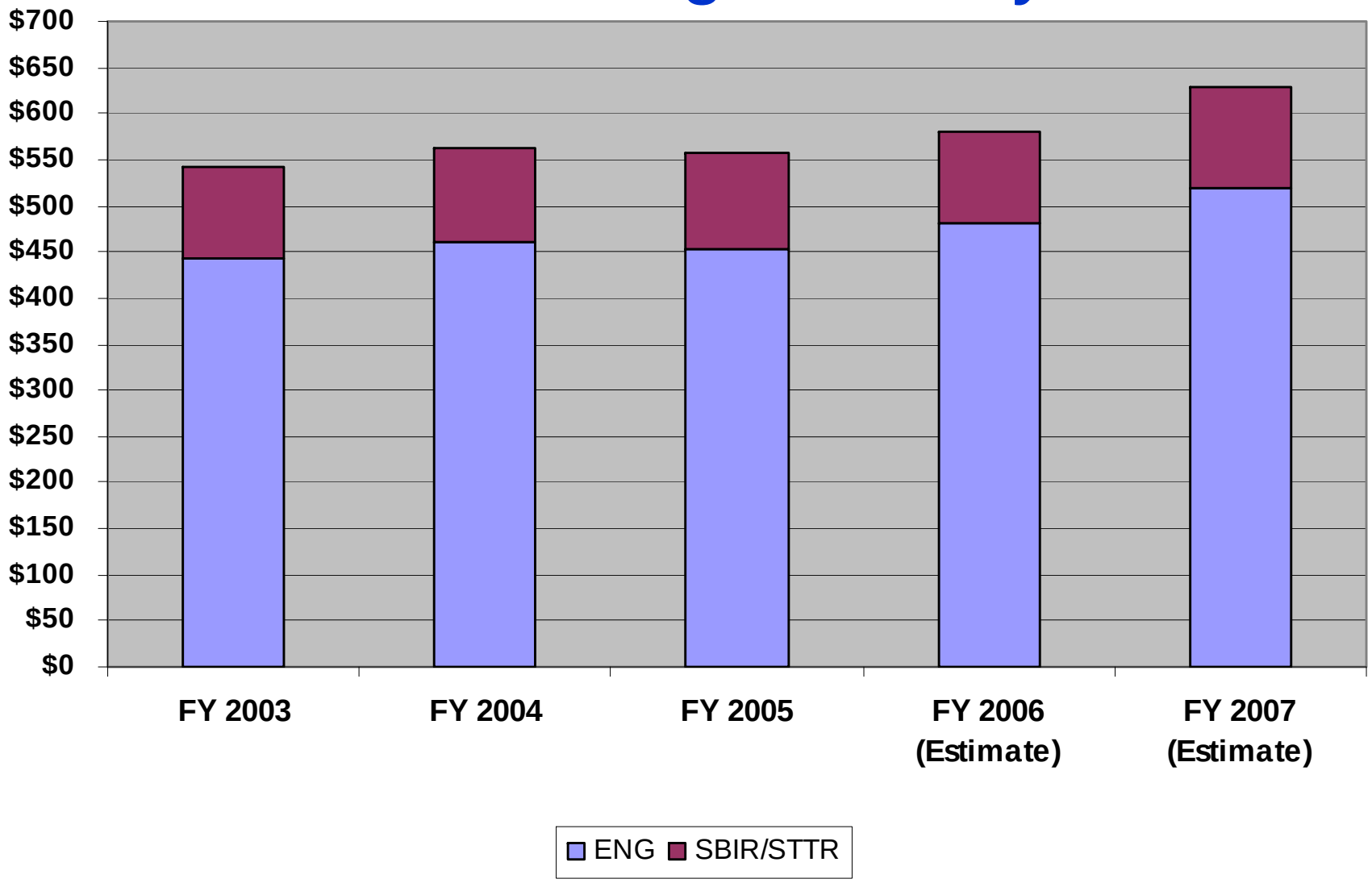
ENG Themes

Nanotechnology

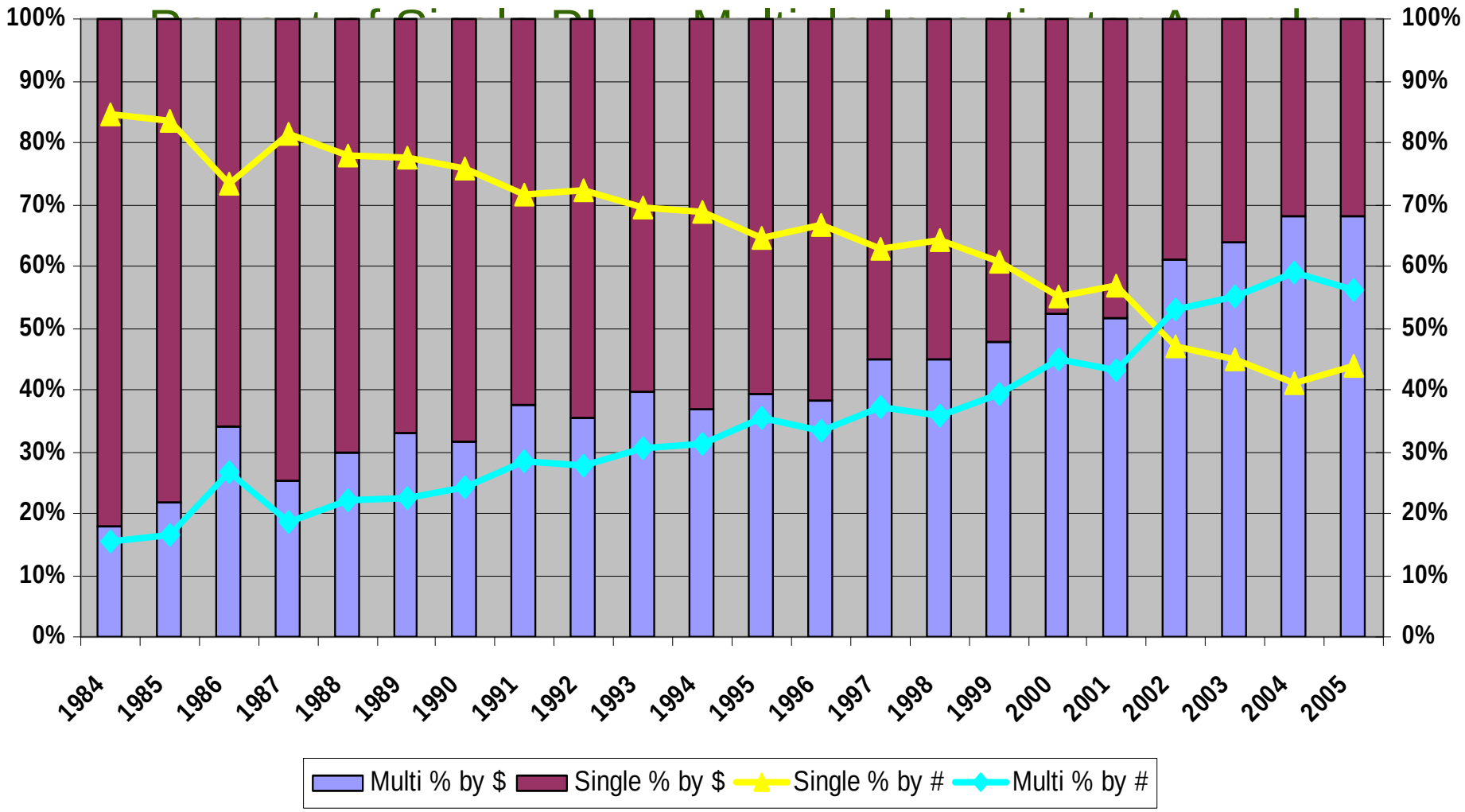


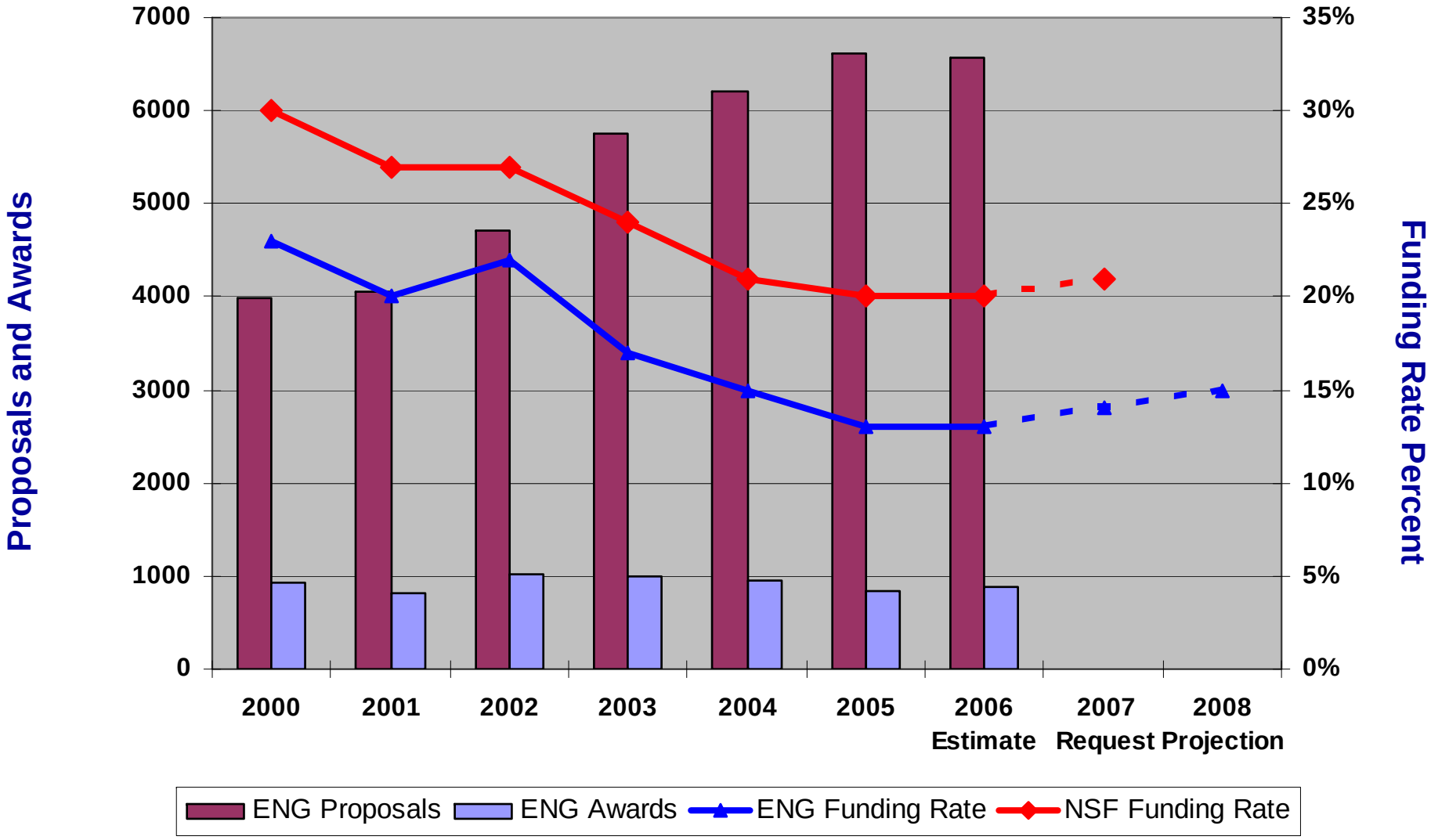
- **NSF is the lead institution in this nation's efforts to develop nanotechnology from a nascent field to a truly path-breaking innovation.**
- **Capabilities in nanotechnology are leading to active and complex nanosystems; and the integration with biology, neurology, energy, and water resources.**
- **Fundamental need for tools to move into the 3rd dimension, and into time resolutions of chemical reactions.**

ENG Budget History



Research Collaborations




Proposals and Awards
Funding Rate Percent
7000
6000
5000
4000
3000
2000
1000
0
35%
30%
25%
20%
15%
10%
5%
0%
2000
2001
2002
2003
2004
2005
2006 Estimate
2007 Request
2008 Projection
ENG Proposals
ENG Awards
ENG Funding Rate
NSF Funding Rate

NSF Program Emphasis in FY 2007

Increased investments will be dedicated to research and education on:

- Increased focus on complex large nanosystems. Research on nanoscale devices and system architecture, dynamic and emerging behavior, and their respective fabrication, will be emphasized
- Increased focused on three-dimensional measurements of domains of engineering relevance with good time resolution
- Converging science, engineering and technology from the nanoscale, by integrating nanosystems into applications (in manufacturing, information systems, medicine, environment, etc.)
- Expanded joint research program addressing potential implications of nanotechnology with NIOSH, EPA and FDA, USDA and NIST
- Earlier educational programs and teaching materials, including for K-12, by using remote access to NSF educational networks (NU, NISE, NNIN)
- Expand partnerships of academic researchers with industry, medical facilities and states through two programs (GOALI, PFI), using the CBAN (Collaborative Board for Advancing Nanotechnology)